

Finishing of Angora Rabbit Fibers

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Abstract Angora rabbit fiber, a luxury animal hair fiber is obtained from Angora rabbit. It has some distinct properties like warmness, fineness, whiteness and softness; however its utilization in the conventional textile clothing is restricted due to its scale structure and ladder type medulla. Medulla, an air occupied area in the middle of the fiber reduces the flexibility and scales are responsible for reducing inter-fiber cohesion during mechanical processing of hair. Due to these demerits, Angora rabbit hair is generally used to develop some specialty products through traditional hand spinning and hand loom. To utilize this hair with other textile fibers, either physical or chemical methods are used, that increase the value as well as performance of the final products. This paper overviews various novel approaches involved in finishing of angora rabbit hair for improvement of value and performance of products.

Keywords: Angora, rabbit, fiber, finishing, textile

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1. Introduction

In textile industry, next to cotton, jute and wool fiber, larger quantities of animal hairs are used in the manufacture of textile clothing and fashion garments. These hair fibers are used alone but often in conjunction with other textile fibers particularly with sheep's wool to produce special effects such as additional beauty, texture, color, softness, resilience, durability and luster. The largest group of these fibers is obtained from related species like goats, camels, rabbits etc., known as "specialty hair fibers" or "luxury fibers". From the classification of luxury fibers based on their source, Angora rabbit hair comes under fur fiber [1,2].

Angora rabbit hair, a specialty hair fiber obtained from Angora rabbit has special characteristics like excellent whiteness, softness, lightness and warmth. It is a costly fiber since it has special characteristics and rare availability. The products of Angora rabbit hair have high demand in elite group of consumers in foreign countries. The staple length of Angora rabbit hair is varied from 25 to 55 mm, fiber diameter is varied from 11 to 20 μ , which may be due to presence of guard hair and fiber medullation is ranged from 80 to 100%. However, like other specialty fibers rabbit hairs also possess difficulty when processed alone due to its lesser scale height and medulla, since they reduce the inter fiber cohesion. Due to these reasons, it is difficult to spin and the fibers tend to slip out of the yarn and shed from the fabric. It is primarily used for items such as sweaters, mitten, baby cloth, shawls and millinery [3,4]. Its chemical properties are similar to that of wool and other keratin fibers. The tip

end of the fiber has the ability to curl which encourages felting. It absorbs considerably lesser dye than wool fiber because of the medulla and its fineness [5,6,7].

2. Finishing of Angora Rabbit Fibers

Finishing is a textile processing, used to improve appearance, impart functionality, and enhance durability as well as processing ability of a textile product. It should also meet the suitable requirements and secure customer satisfaction. For example, shirting and leisurewear must have an acceptable handle, should not crease in wear and should display good easy-care properties. Similarly, work wear must be resistant to hazards met by the wearer, like suits worn by automobile mechanics must have enough oil and stain repellency, firefighters' uniforms must be fire proof and outdoor wear must be water-repellent. It has done by physical, chemical, biochemical and physico-chemical methods and the durability of the finishes may be temporary or permanent [8]. The suitable finishing process in order to improve Angora rabbit hair's value and performance can be classified as per Table 1.

Table 1. Classification of finishing methods suitable to Angora rabbit hair

A. PHYSICAL METHODS	1. Blending with other textile fibers 2. Physical treatment of fibers for surface modification
B. CHEMICAL METHODS	1. Chemical treatment of fibers for product development 2. Chemical finishing of fabric to improve its functionality

2.1. Physical Methods

2.1.1. Blending with Other Textile Fibers

2.1.1.1. Blending with Wool

Research works were carried in Central Sheep and Wool Research Institute, Avikanagar, India by blending Angora rabbit hair with wool, cotton, polyester, acrylic and silk staple fiber for the development of different blended yarn. They spun the blends in the cotton and woolen spinning systems and found that there was ample scope to improve processing of rabbit hair in blends further. They also inferred that 25:75 angora rabbit hair/fine wool blend based yarns / shawls / knitwear have better bulk, softness, whiteness, warmth, stretch and recovery than 100% fine wool products [9,10,11,12,13].

In Himachal Pradesh of India, local artisans are generally used hand spinning charkha for producing 100% Angora rabbit hair yarn and used handloom for shawl. They observed that >10% fiber loss was occurred during preparation of shawl, since rabbit hair yarn was thicker than 100% fine wool yarn, however it has uniform thickness. To reduce the fiber loss, they preferred 2/48's fine wool yarn as warp and 100% Angora rabbit hair yarn as weft for the weaving of shawl in handloom. However, weaving of such luxurious products from pure Angora rabbit hair yarn requires highly skilled artisans and manpower. Due to its good felting ability, it is used to blend with fine wool waste for the development of fancy felt products [14].

2.1.1.2. Blending with Viscose Staple Fiber

Angora rabbit hair must be a static-free fiber for blending with cotton or viscose staple fiber. Angora rabbit hair was pretreated with 5% sodium hydroxide (over weight of the material) at room temperature in order to reduce static charge during spinning and to improve inter fiber cohesion. It was found that sodium hydroxide treatment would improve the swelling of scales as well as hydrophilic nature of fiber, which reduces the static charges. The sodium hydroxide treated hair was blended with staple viscose rayon fiber in 20:80 ratios. The blended fiber mixture was fed directly into a carding machine and spun in the conventional cotton spinning system and blend yarn of 21's was developed. The tenacity and count strength product of the blended yarn were 7.84 g/Text and 1358 respectively. The Uster percent and percent hairiness index of yarn are 12.09 % and 6.48% respectively, which are in acceptable limit for the production of quality woven and knitted fabric. The thin and thick places per kilometer are 6 and 67 respectively and total imperfection per kilometer is 117, which was higher than standard 1/30 viscose yarn (90) due to presence of rabbit guard hair, but it is lower than 1/30's carded cotton yarn (465). This study inferred that sodium hydroxide treated Angora rabbit hair can be blended with viscose staple fiber in 20:80 ratios and the respective yarn could be useful for the production of quality woven fabric [15].

2.1.1.3. Blending with Cotton

Angora rabbit hair was blended with cotton fibers, spun in to 40s count yarn and made into knitted garments. It was reported that up to 30% of Angora rabbit hair in the blend was acceptable for spinning the yarn which was suitable for weaving. The soft feel and low shrink

properties of knitted fabrics were found suitable for innerwear [16].

2.1.2. Physical Treatment of Fibers for Surface Modification

National Institute of Design, Ahmedabad, India in collaboration with Institute for Plasma Research, Gujarat, India had developed a prototype plant for generation of atmospheric pressure plasma. This plant was used to generate plasma at atmospheric pressure using air / nitrogen as plasma forming gas and applied to Angora rabbit hair sliver. It was found that plasma treatment in presence of helium gas (inert atmosphere) for 10 minutes could increase the friction and cohesion between the fibers with slight reduction in denier and increase in tenacity. It could lead to development of 100% Angora rabbit hair based winter garments suitable for soldiers in the sub-zero hilly region of India. The physical properties of plasma treated and untreated Angora rabbit hair are given in Table 2 [17].

Table 2. Physical properties of treated and untreated Angora rabbit hair

S.No	Parameters	Untreated	Plasma treated
1	Fiber fineness(denier)	1.97	1.90
2	Fiber diameter(μ)	17.46	17.15
3	Breaking strength (cN)	3.18	3.59
4	Breaking extension (%)	40.47	40.27
5	Tenacity (cN/d)	1.61	1.89
6	Friction co-efficient	0.10	0.30

2.2. Chemical Methods

2.2.1. Chemical Treatment of Fibers for Product Development

2.2.1.1. Chemical Pretreatment of Angora Rabbit Hair

Chemical treatments are used to modify the chemical nature of the surface of the textile fiber, which also leads to improve its processing ability and performance. Physio-chemical, mechanical properties and morphological components of angora rabbit hair such as fiber diameter, fiber length, fiber strength, urea-bisulphite solubility, fiber swelling, cortex content, medulla content and dye uptake was studied in order to find its suitability in the blending with different wool fibers. From this study, it is inferred that Angora rabbit hair has some close resemblance with fine wools in physical characters except crimp frequency and medulla. The behavior of Angora rabbit hair towards various chemical treatments such as thioglycollic acid reduction, sulphytolysis, formic acid, morpholine, sodium hydroxide and protease enzyme treatment is also similar to that of wool fibers. It is concluded that, there is a possibility of utilizing Angora rabbit hair after suitable chemical pretreatment for the production of valuable textiles and garments by blending the wool fiber. Among the chemical treatments, alkali treatment is found suitable chemical treatment to improve swelling and dyeing properties of Angora rabbit fibers with tolerable loss in fiber strength [18].

Research works were carried by pre-treating the Angora rabbit hair with acetic acid / sulfur dioxide / low

temperature plasma in order to reduce the static charges formed during spinning. The treated hairs were spun in different spinning system to produce 100% Angora rabbit hair yarn. A process was patented for producing 100% Angora rabbit hair yarn. It comprised treatment of Angora rabbit hair with a chemical combination containing a bleaching agent in order to increase the crimps on the surface of the Angora rabbit hair. The application of a conventional softening agent and an antistatic agent on pretreated hair was increased its spinning ability in the worsted spinning system similar to fine wool [17,19,20,21].

2.2.1.2. Enzyme Pretreatment of Angora Rabbit Hair

Angora rabbit hair is differed from fine wool in whiteness because it has lesser added impurities than wool since rabbit is not grazed in the field. To compensate the whiteness difference between fine wool and Angora rabbit hair, an alkaline protease enzyme treatment was applied and dyed with five different classes of dyestuff. It is observed that there is an improvement in depth of color after enzyme treatment in both fibers, but rabbit hair has shown lesser K/S value than fine wool. The color yield value (K/S) of fine wool and Angora rabbit hair with and without enzyme treatment is given in Table 3.

Table 3. Color yield (K/S) value of dyed fibers before and after enzyme pretreatment [23]

Process →	Without Enzyme pretreatment		With Enzyme pretreatment	
	Wool fiber	Rabbit hair	Wool fiber	Rabbit hair
Leveling Acid dye	2.35	1.62	2.68	1.71
Acid milling dye	3.31	2.84	3.69	3.03
Reactive dye	3.12	2.31	3.58	2.37
1:1 MC dye	3.81	3.15	3.92	3.24
1:2 MC dye	4.13	3.24	4.37	3.52
<i>MC- Metal Complex</i>				

Rabbit hair has nearly 85-90% medullated fibers while fine wool fiber has <1 % medullation. The air filled medulla in rabbit hair produces a different light refraction than wool (optical phenomenon) as a result the fiber appears much paler after dyeing in comparison to those without medullae. Also fibers of this type contain insufficient cortex to take up adequate amounts of dye [22,23].

2.2.1.3. Ozone Pretreatment of Angora Rabbit hair

An ozone treatment for angora wool was optimized by differentiating fiber moisture, pH, and treatment time in order to impart bleaching effect similar to hydrogen peroxide bleaching. The study inferred that ozone treatment gave more degree of whiteness and dye ability of Angora rabbit fiber than untreated hair [24]. Similarly ozone pretreatment followed by dyeing in presence of ultra-sonication improved the dyeability of angora fiber significantly better than only ozone treated hair [25].

2.2.2. Chemical Finishing of Fabric to Improve Its Functionality

2.2.2.1. Softening

Cotton yarn is generally used as warp yarn for the development of union fabric with wool / jute and it could be used as fancy garments or upholstery. A union fabric was prepared by using 23's sodium hydroxide treated Angora rabbit hair: viscose rayon fiber (20:80) blended yarn as weft and 2/40's cotton yarn as warp, and they plain woven fabric in a power loom. This union fabric was enzyme desized, mild scoured and cold bleached with hydrogen peroxide in order to safe guard the rabbit hair. The bleached fabric was dyed with acid dye/reactive dye combination and finished with eight different commercially available softness finishing combinations. The shrinkage of grey fabric was 8.1% due to the presence of viscose rayon fiber in the fabric and the finished fabric has shown less than 4%, which is in an acceptable limit. The drape coefficient of all finished fabrics ranged between 41 and 52% and the better drape is observed in nano-polysiloxane based finished fabric (41%).

The retention of tearing strength of finished fabric in warp direction was ranged from 90 to 110%; while in weft direction it ranged from 105 to 135%, which inferred that there is no reduction of tearing strength in weft direction after finishing, hence this blended weft yarn could improve the durability of the finished fabric. After finishing the bending length of the fabric was slightly increased in warp direction due to presence of rabbit hair while in weft direction there was no change. It was concluded that, Angora rabbit hair based blended products could be finished with either micro-polysiloxane or cationic softener + micro polysiloxane + macro polysiloxane combination finishing to impart soft feel suitable to garment production [26,27,28].

Another research work has carried by blending Angora rabbit with fine wool in three different proportions viz. 28:72, 40:60 and 60:40 for the development of value added shawls by spinning the blends in the modified cotton system and woven in a power loom. The shawls were bleached with peroxide bleaching, dyed with reactive dye and finished with a cationic softener by exhaust method. Properties of three different shawls are given in Table 4.

Table 4. Performance properties of Angora rabbit hair-fine wool blended shawls [33]

Material → Properties ↓	RH:BM - 28:72		RH:BM - 40:60		RH:BM - 60:40	
	Warp	Weft	Warp	Weft	Warp	Weft
Bending length (cm)	1.67	1.70	1.63	1.65	1.61	1.49
Frictional force (g)	199	204	197	199	195	197
Abrasion Loss (%)	5.4		3.4		3.6	
Thermal insulation (Tog)	1.476		1.560		1.704	
<i>RH- Angora Rabbit hair; BM-Bharat Merino wool</i>						

Results inferred that bending length and frictional force of 60:40 Angora rabbit hairs: wool blended shawl shown higher softness than other shawls. Softness was also increased with the increase in the proportion of rabbit hair in the shawl. The thermal insulation value (Tog) was increased as the proportion of Angora rabbit hair is increased and so 60:40 blended shawl shown higher Tog value than other shawls [33]. Being a medullated fiber, it increases the bulkiness and hairiness of the final product

which encapsulate the air between the entangled fibers and fabric surface. The trapped air has lower thermal conductivity than the fibers, which improved the thermal insulation of the shawl [34,35].

2.2.2.2. Antimicrobial Finishing

Natural antimicrobials like turmeric, aloe Vera have been used to impart antimicrobial activity. Angora rabbit hair was applied with natural antimicrobial ingredients such as *aloe vera*, chitosan and curcumin separately as well as combinations with each other. They were applied to the Angora rabbit hair with and without prior formic acid treatment in order to find the effect of pretreatment. They were applied by exhaustion method at 95°C for 60 minutes. It was found that formic acid pretreatment increases the wettability; decreases the diffusion barrier; increases anionic character and also increases the critical surface tension of Angora rabbit hair. These factors enhance the spreading and adhesion of the antimicrobial ingredients on the fibrous surface [29].

Antimicrobial activity of natural ingredients treated Angora rabbit hair was assessed by Quinn method. It was found that the residual impurities present in the natural fibers influence the growth of microbial and lowering the uptake of antimicrobial ingredient in the fibrous substrate. After formic acid treatment followed by application with natural ingredients in individual and combination form Angora rabbit hair shown better resistance against microbial in combination form than individual form. The morphological changes in surface of Angora rabbit hair after treatment with formic acid and natural ingredients are shown in the Figure 1.

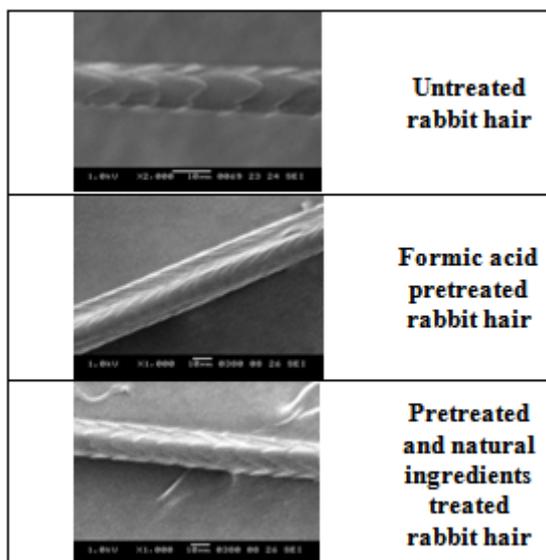


Figure 1. SEM photographs of different rabbit hair [31]

The reasons behind the antimicrobial activity of natural ingredients are explained as follows. Acemannan, anthraquinone, and salicylic acid present in *aloe vera* help to promote antimicrobial activity and it is further enhanced by amino acids, zinc and saponins present in it. Chitosan form ionic interaction between the carboxylate groups (COO^-) of rabbit hair and the protonated amino groups of chitosan (NH_4^+) along with H-bonding and van der Waals' forces. These interactions are known to be weak and hence chitosan affinity in rabbit hair can be

generally regarded as weak and so it is not able to give good antimicrobial activity when applied alone.

Curcumin has only phenolic groups, which form hydrogen bonding with amino / hydroxyl groups of rabbit hair. When the natural antimicrobial ingredients are applied in combination form, the antibacterial activity is better in aloe Vera combinations than non-aloe vera combination. The protonated amino groups of chitosan increases the attractive forces to nucleophiles present in aloe vera and enhanced their uptake. The amino acids present in exhausted aloe vera form salt linkages with functional groups of rabbit hair. These chemical bonding lead to maximum fixation and improve the antimicrobial activity of natural ingredients in the hair. It was also observed that antimicrobial activity of formic acid treated and natural ingredients treated Angora rabbit hair durable up to twenty five washes [30,31].

2.2.2.3. Enzymatic Finishing

Angora rabbit has resemblance with fine wool except in medulla component and so it can be finished with finishing chemicals suitable for woolen products. Alkaline protease enzyme treatment followed by pre-polymer resin finishing is used to felting shrinkage of woolen products. Similarly 1% protease enzyme pre-treatment followed by resin finishing evidently prevent the shedding of Angora rabbit hair from knitted fabric with less damage to the fiber. It was also suggested that 50g/L resin finishing gave the best effects [32].

3. Future Prospects

Angora rabbit hair has a distinguish place in the fashion market and it also competes with luxurious natural fibers for its sustainability. The main drawback of the Angora rabbit hair is its poor inter fiber cohesion which compels the processor to develop Angora rabbit hair based products by traditional technologies like charkha and handloom. These processes are laborious, time consuming and fetch marginal profit. To survive the Angora rabbit hair industry, it is the right time to implement some novel approaches for the betterment of diversified products from them. Such approaches could also increase the utilization of Angora rabbit hair which improves the economy of artisans involved in the agora rabbit husbandry. The important possible approaches for diversification and value addition of Angora rabbit hair are given below.

1. Angora rabbit is one of the costliest fibers, and their products are not affordable by each people. It is better to develop blended products by blending it with various natural fibers. It can reduce the cost of the final product as well as increase the consumption of Angora rabbit hair in other fields in a shorter duration, which increase its demand like other luxurious fibers in market [36].
2. Spinning and weaving of Angora rabbit hair is a laborious work. Suitable technology intervention is required to reduce the processing time by modifying the conventional spinning and weaving either by semi-automation or reduce wear and tear.
3. Being medullated fiber, processors might be preferred this hair to give fancy effect on fashion garments

4. Some well-adopted finishing technology used for woollen textiles like nano repellent finishing, aromatic finishing and fragrance finishing can be standardized for small scale sectors and applied to Angora rabbit hair products. This value addition can be used to increase diversification of products as well as demand in the market [37,38,39]
5. Natural dyes those able to various colors with different metallic mordants or tannic acid along with antimicrobial activity can be applied [40,41]
6. Plasma, an environmental friendly zero water process can be applied to fine wool/angora rabbit hair blended products for development of fancy or mélangé products [42,43].

4. Conclusion

Present days Angora rabbit hair based products accessible to people in the hilly region and some part of the fashion markets of the developed countries only. It did not meet the requirement of regular clothing markets due to difficulty in its spinning. Also due to limited production of this hair in the world, people did not have awareness on it. Research information on surface modification of Angora rabbit hair for its value addition with other textiles fibers and their product development is still in scanty. By utilizing this hair in the conventional apparels and home textiles by blending with other textile fibers in acceptable level (10-30%) along with proper finishing technologies from fiber stage (pretreatment) to garment stage (softening), we could streamline the marketing of different angora rabbit hair based products.

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